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Abstract

This paper looks into potential determinants of the mode of international competition in a polluting good market by analyzing a strategic interaction between two environmentally concerned governments. From the equilibrium outcomes of our game based on an international duopoly model with transboundary pollution, we show how a resulting form of international competition can be influenced by, among other things, the magnitudes of the marginal damage cost and transboundary impact of pollution and also the degree of similarity between the two nations in these aspects.

Keywords: international duopoly, transboundary pollution, gains from trade.

JEL Classification: F10, F12, Q20.

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1 Introduction

The large literature on the gains-from-trade proposition initiated by Samuelson (1939) generally asserts that free trade is gainful to all the participating nations. Moreover, the so-called 'new trade theory' which incorporates imperfect competition and/or increasing returns has found a new source for gains from trade. Among others, Markusen (1981) makes it clear that the opening of trade promotes competition, from which trading countries can gain. However, environmental considerations are usually missing in the existing literature on gains from trade under imperfect competition although environmental considerations seem to play an increasingly important part in recent negotiations over more liberalized trade regimes at both global and regional scales. This is exemplified in the debates over NAFTA where freer commercial interactions in North America was opposed by some partly on the ground of environmental protection. Similar arguments have been frequently made by citizen groups who persistently resist so-called globalization, as was symbolically manifested in their feverish oppositions towards the World Trade Organization (WTO) Round Talk in Seattle in 1999.

As is easily imaginable, possible existence of gains from international trade in a polluting product is dependent on the market structure as well as the preferences of citizens. On top of these, when the pollution issue is transboundary by nature, the welfare impact of international trade could also depend on the physical characteristics of a pollution issue. The welfare implications of environmental variables in transboundary pollution problems have been typically investigated in game-theoretic studies without accounting for international trade. Important examples of such studies are Mäler (1990) and Tahvonen, Kaitala, and Pohjola (1993) for flow pollution, and Kaitala, Pohjola and Tahvonen (1992) and Mäler and de Zeeuw (1998) for stock pollution.

Conversely, though, there might be situations where the form of an international competition in a polluting good market should not be given *a priori* and can be influenced by the characteristics of the environmental problem at hand. This paper aims to explore such a possibility by explicitly modeling the strategic interaction surrounding governmental decision makings which, consequently, determine possible modes of international trade in the presence of transboundary pollution associated with the production of a potentially tradable good. In particular, we demonstrate that both Stackelberg and Cournot-Nash types of duopolistic competition, in addition to the autarkic situation, are possible equilibrium outcomes, depending upon the magnitudes of marginal damage cost and transboundary impact of pollution, as well as how similar the concerned nations are in these aspects.

This paper proceeds as follows. Section 2 presents our basic model of an economy with transboundary pollution and derives its autarkic outcome. By extending the model to a two-country world, the next section characterizes potential free trade outcomes under two different modes of international competition. Then, Section 4 describes our inter-governmental game whose result determines the structure of an international market of a polluting product and discusses the implications of its equilibrium outcomes. The last section contains brief concluding remarks.

2 Autarky

This section develops our basic model and describes its autarkic outcome. The model is comprised of two countries (Home and Foreign), two goods (Goods 1 and 2), and one primary factor (labor). We assume that both countries share the identical preferences and production technologies, and produce both goods. In the following description of our model, we focus on Home since the Foreign country can be described symmetrically. We denote each Foreign variable by attaching an asterisk (*). Furthermore, Good 2 serves as a numeraire and is produced with a unitary input coefficient so that the wage rate is internationally equalized and fixed at unity. In the autarkic case, Good 1 is monopolistically supplied by a single domestic firm and $c > 0$ units of labor are required to produce one unit of Good 1. Hence, the marginal cost of production is assumed to be constant at c. In addition, the production of one unit of Good 1 entails one unit of pollutant emissions.

Now, let us suppose that the utility function of a representative consumer in Home can be specified by

$$V = AC_1 - \frac{C_1^2}{2} + C_2 - \frac{s}{2}Z^2, \quad A > 0, \quad s > 0, \tag{1}$$

where V is the consumer's utility level, $C_i,\ i = 1, 2$, is the consumption of each good, and Z is the pollution level in this country. We assume that the pollution generation associated with the consumption of Good 1 is treated as a negative externality by this consumer and, therefore, out of its control. Letting p denotes the price of Good 1 measured by the price of Good 2, utility maximization subject to the budget constraint yields the demand function of Good 1:

$$C_1 = A - p.$$

Under autarky, the market-clearing condition is

$$A - p = x,$$

where x is the output of Good 1. Hence, the inverse demand function and the monopoly firm's profit are respectively defined by

$$p = A - x, \tag{2}$$

$$\pi \equiv (A - c - x)x. \tag{3}$$

Using (2) and (3), the social welfare of the nation, U, which is the sum of the consumer surplus, the monopolist's profit, and the environmental damage cost of the pollution, can be expressed as

$$U = \frac{(A-p)^2}{2} + \pi - \frac{s}{2}Z^2. \tag{4}$$

In the subsequent analysis, (4) determines a payoff of the government in each situation.

As for the transboundary effect of the pollution, we assume that one unit of Foreign's (resp. Home's) pollutant emissions x^* (resp. x) increases Home's (resp. Foreign's) ambient pollutant level by the fraction of $\alpha \in [0, 1]$ (resp. α^*) while one unit of domestic emissions increases its own ambient pollutant level by one unit. The values of α and α^* are what are sometimes referred to as 'transportation coefficients', but we instead call them 'pollutant import coefficients' here in order to emphasize the directions of the pollutant flow. In the case of global pollution, such as CO_2 that is a culprit of the global warming problem, we have $\alpha = \alpha^* = 1$, while both α and α^* are normally strictly smaller than one and take different values in so-called regional environmental issues, such as the transboundary acid rain problem in Northern Europe. When $\alpha = \alpha^* = 0$, on the other hand, the pollution problem is completely localized. In sum, the pollution levels in respective countries are described as

$$Z = x + \alpha x^*, \tag{5}$$

$$Z^* = x^* + \alpha^* x. \tag{6}$$

Let us now formulate the optimization problem of each country's firm. Again, we focus on the Home firm since its Foreign counterpart behaves in exactly the same fashion. Specifically, the Home firm solves the following problem in the autarkic case:

$$\max_x \ (A - c - x)x,$$

whose solution can be immediately obtained as

$$x^A = \frac{A - c}{2}, \tag{7}$$

where the superscript A represents the autarkic outcome. Also, the autarkic price is derived from the demand function as

$$p^A = \frac{A + c}{2}. \tag{8}$$

Substituting (7) and (8), as well as (3) and (5), into (4), the payoff of the Home government in the autarkic outcome can be calculated as

$$U^A = \frac{3 - s(1+\alpha)^2}{8}(A - c)^2. \tag{9}$$

It should be noted that, even under autarky, the welfare of Home is affected by the production level in Foreign through the transboundary pollution in (5). Hence, there exists a negative externality associated with the production of Good 1 across the two countries. The next section extends this model to an international duopoly in two different modes of competition.

3 International duopoly

When the two domestic markets of Good 1 described above is fully integrated internationally, the new market-clearing condition becomes

$$C_1 + C_1^* = 2(A - p) = x + x^*,$$

which is inverted to yield

$$p = A - \frac{x + x^*}{2}. \tag{10}$$

This defines the inverse demand function for Good 1 in the international market of Good 1 and each firm's profit function becomes

$$\pi = \left(A - c - \frac{x + x^*}{2} \right) x.$$

First, we consider the case where the two firms are engaged in a Cournot-type competition in this international market. In essence, these firms determine their respective output supply levels concurrently. Specifically, these two firms respectively attempt to solve the following optimization problems:

$$\max_{x} \ \pi = \left(A - c - \frac{x + x^*}{2} \right) x,$$
$$\max_{x^*} \ \pi^* = \left(A - c - \frac{x + x^*}{2} \right) x^*.$$

One can immediately obtain the first-order conditions:

$$A - c - \frac{x^*}{2} - x = 0,$$
$$A - c - \frac{x}{2} - x^* = 0,$$

which lead to their respective reaction functions:

$$x = A - c - \frac{x^*}{2}, \tag{11}$$
$$x^* = A - c - \frac{x}{2}. \tag{12}$$

Solving these equations simultaneously, we can obtain the Cournot-Nash equilibrium levels of output supply for the two firms:

$$x^C = x^{*C} = \frac{2(A - c)}{3}. \tag{13}$$

Furthermore, the equilibrium price becomes

$$p^C = \frac{A + 2c}{3}. \tag{14}$$

Comparing (8) and (14), we can easily confirm $p^C < p^A$, which implies that the procompetitive effect of the opening of international trade emerges in our model.

Moreover, the payoff of the Home government can be obtained by substituting (13) and (14), together with (3) and (5), into (4). Consequently, we have the Home government's payoff as

$$U^C = \frac{4 - 2s(1+\alpha)^2}{9}(A-c)^2.$$

As another possible mode of international duopoly under free trade, we also consider the case where the two firms are engaged in a Stackelberg type competition. In a Stackelberg duopoly game, the leading firm is somehow able to make a credible commitment with respect to the supply level of Good 1 prior to its follower.

Substituting (12) into the definition of π above, the Home firm's profit function, when it acts as the Stackelberg leader, can be described as

$$\begin{aligned} \pi &= \left(A - c - \frac{x + x^*}{2}\right) x \\ &= \left(\frac{A-c}{2} - \frac{x}{4}\right) x. \end{aligned}$$

Thus, from the profit maximization problem of this Stackelberg leader, we can easily derive the following levels of output supply in this Stackelberg equilibrium:

$$x^L = A - c, \tag{15}$$

$$x^F = \frac{A-c}{2}, \tag{16}$$

where x^L and x^F respectively denote the output levels of the leader and the follower. Furthermore, the equilibrium price, p^S, becomes

$$p^S = A - \frac{x^S + x^{*S}}{2} = \frac{A+3c}{4}. \tag{17}$$

Comparing (14) and (17), we can observe $p^S < p^C$, i.e., the price of Good 1 is lower under the Stackelberg competition than under the Cournot-Nash competition. Hence, the procompetitive effect of international trade is strengthened further in the Stackelberg outcome.

Finally, substituting (15)-(17), together with (3) and (5), into (4), we have the payoffs of the countries with the leader firm and the follower firm, respectively, as

$$U^L = \frac{17 - 4s(2+\alpha)^2}{32}(A-c)^2, \tag{18}$$

$$U^F = \frac{13 - 4s(1+2\alpha)^2}{32}(A-c)^2. \tag{19}$$

4 The inter-governmental game

In this section, we introduce a game between Home and Foreign governments over their respective firms' roles in the international market of Good 1. This game takes place prior to the international duopoly game described above, and the players are the governments of the two nations, instead of the firms themselves as is commonly supposed in so-called endogenous-timing studies.[1] Here, we suppose that the government can intervene the market only as regards the timing of the participation of its own firm in the international market of Good 1 and it does not possess any other kinds of policy measures. Such a setup could be supported by the argument that, although the implementation of an environmental policy might be difficult for informational and/or institutional reasons, a national government would be able to control the openness of its market relatively easily.

For simplicity, the strategy space of this inter-governmental game is restricted to {1, 2, no trade} and we only consider pure strategies. The two governments' actions effectively commit their own firms to the specific timings of entering into the international duopoly, and jointly determine their respective roles in this market. When one government chooses 1 and the other chooses 2, the former nation's firm assumes the role of the Stackelberg leader in the international duopoly, while the firm in the latter country becomes the Stackelberg follower. When the two governments choose the same number, the mode of international competition becomes that of the Cournot-Nash type, i.e., the concurrent choices of output supply levels by the two firms. Moreover, we suppose that a firm cannot export its product when its government decides to close the domestic market to import from the other country. Hence, when at least one of the two governments chooses 'no

[1] Syropoulos (1994) analyzed the endogenous timing game of governmental trade interventions with different kinds of policy instruments in a similar framework to Hamilton and Slutsky (1990). Our model differs from his framework, especially, in that an outcome of our governmental interaction determines the timings of moves in a game where the government themselves do not participate directly.

trade', the autarkic situation arises in each country. The payoff matrix of this game is described in Figure 1, with all the payoff values respectively corresponding to the ones described in the preceding sections.

(Figure 1 around here)

As we discuss below, the subgame-perfect Nash equilibrium outcomes of this whole game can be categorized into several different classes, depending upon the values of s, the marginal cost of pollution, and α, the transboundary pollutant import coefficient, as well as upon whether the two countries are symmetric or not. Observing Figure 1, in combination with the payoffs of the governments under different circumstances obtained above, we can derive the Nash equilibrium outcomes of this inter-governmental game and, therefore, the subgame-perfect Nash equilibrium outcomes of the whole game, possibly including the international duopolistic competition between the two firms afterward unless the outcome of the inter-governmental game is 'autarky'.

4.1 Symmetric case

We begin our analysis of the inter-governmental game above with a simple case where the two countries share the same values of s and α. That is, we suppose that $s = s^*$ and $\alpha = \alpha^*$ in this subsection. Since the two countries are completely symmetric in these respects, we focus on Home for the description of this subsection. In this case, we have only two possible equilibrium outcomes. The finding is summarized in the following statement.

Proposition 1. *The Cournot-Nash competition in the international market can be a subgame-perfect Nash equilibrium outcome for the values of* s *and* α *that satisfy the following inequality. Otherwise, autarky is the only possible equilibrium outcome.*

$$s < \frac{5}{7(1+\alpha)^2}. \tag{20}$$

Proof. By construction, the autarkic situation always constitutes a subgame-perfect

Nash equilibrium of the whole game. This is because, whatever action it may take, a government's payoff is the same autarkic one when the other government chooses 'no trade' in the inter-governmental game. We now attempt to show that the Cournot-Nash competition can also be an equilibrium outcome under certain conditions. In order for the Cournot-Nash type competition to be a subgame-perfect Nash equilibrium in addition to the autarkic situation, the government must, at least, prefer the Cournot-Nash outcome to the autarkic one. Taking the ratio of U^A and U^C, we have

$$\frac{U^A}{U^C} = \frac{27 - 9s(1+\alpha)^2}{32 - 16s(1+\alpha)^2}, \tag{21}$$

and setting $U^A/U^C < 1$ yields (20). Moreover, it is easy to show that the Stackelberg outcome cannot be an equilibrium under any circumstance. In view of Figure 1, this amounts to confirming that there is no circumstance under which one government wishes its firm to be the Stackelberg leader and the other wishes its firms to be the Stackelberg follower at the same time, in comparison with having their firms compete in the Cournot-Nash fashion. We start by deriving the condition under which the government prefers to have its firm become the Stackelberg leader to letting its firm become one of the Cournot-Nash competitors. Taking the ratio of U^L/U^C , we have

$$\frac{U^L}{U^C} = \frac{9[17 - 4s(2+\alpha)^2]}{32[4 - 2s(1+\alpha)^2]}, \tag{22}$$

and setting $U^L/U^C > 1$ leads to

$$s < \frac{25}{4(2-\alpha)(10+7\alpha)}. \tag{23}$$

On the other hand, the government would be better off by having its firm become the Stackelberg follower rather than a Cournot-Nash competitor if $U^F/U^C > 1$ holds. Taking the ratio of U^F/U^C, we have

$$\frac{U^F}{U^C} = \frac{9[13 - 4s(1+2\alpha)^2]}{32[4 - 2s(1+\alpha)^2]}, \tag{24}$$

and setting $U^F/U^C > 1$ leads to[2]

$$s > \frac{11}{4(1-2\alpha)(10\alpha+7)}. \tag{25}$$

[2]Condition (25) is meaningful only if $\alpha < 1/2$ because $U^F > U^C$ trivially holds for any $\alpha > 1/2$.

As is shown in Figure 2 in the $\alpha - s$ space, we can easily confirm that there is no combination of s and α that satisfy (23) and (25) simultaneously. Hence, the Stackelberg outcome cannot be an equilibrium in the symmetric country case. **Q.E.D.**

Proposition 1 implies that, given the pollutant import coefficient (α), the government would be strictly better off by remaining in the autarkic situation when the marginal cost of the pollution (s) is sufficiently high. Under such a circumstance, consequently, the international trade of Good 1 does not materialize between the two countries. In other words, if a country is sufficiently sensitive to the transboundary pollution, in terms of high environmental damage cost and/or high vulnerability to external pollutant emissions, it rationally opts for autarky for the fear of increased environmental damages from the pollution, even though free trade in the good itself could be mutually gainful. The region that satisfies the condition for the realization of this outcome is depicted as region A in the $\alpha - s$ space in Figure 2. On the other hand, the region where the Cournot-Nash competition in the international market brings net gain from trade to each country is indicated as region C. In the context of our endogenous timing model, there is no possibility of a Stackelberg-type competition in the international market in the symmetric case.

(Figure 2 around here)

Quite similarly to any other values of the pollutant import coefficient, in the two extreme cases of $\alpha = 0$, i.e., when the pollution problem is completely localized and $\alpha = 1$, i.e., when the problem is global, both autarky and Cournot-Nash type competition are possible equilibrium results. The exact outcome depends on the magnitude of marginal damage cost of pollution, s. In the case of localized pollution, only autarky realizes if $s > \frac{5}{7}$ and Cournot-Nash type competition can realize if $s < \frac{5}{7}$. In the global pollution case, $\frac{5}{28}$ is the threshold value, instead of $\frac{5}{7}$. In fact, since the line, $U^A = U^C$, is monotone decreasing in α as can be observed in Figure 2, we conclude that the gain from trade is more likely to materialize as the pollution issue is more localized in this symmetric case.

4.2 Asymmetric case

When the two countries are asymmetric in terms of having different values of the marginal cost of the pollution (s) and the pollutant import coefficient (α), a Stackelberg type competition can also become a Nash equilibrium outcome of the inter-governmental game. In order to simplify the descriptions, as a possible form of Stackelberg-type competition, we focus on the case where Home's firm is the Stackelberg leader and Foreign's firm is the follower. It should be noted that exactly the same argument holds even when the roles in a Stackelberg equilibrium are reversed between the two firms.

Before showing the possibility of a Stackelberg case as an equilibrium outcome, we first present the next statement concerning the Cournot-Nash outcome.

Proposition 2. *When s, α, s^*, and α^* satisfy the following two conditions,*

$$s < \frac{5}{7(1+\alpha)^2}, \tag{26}$$

$$s^* < \frac{5}{7(1+\alpha^*)^2}, \tag{27}$$

and, in addition, one of the following two conditions, the Cournot-Nash competition becomes an equilibrium outcome and both countries can potentially gain from trade:[3]

$$s > \frac{25}{4(2-\alpha)(10+7\alpha)}, \tag{28}$$

$$s^* < \frac{11}{4(1-2\alpha^*)(10\alpha^*+7)}. \tag{29}$$

Proof. When (26) and (27) are satisfied for the respective countries, both of them can gain by moving from autarky to the Cournot-Nash type competition under free trade. However, a Stackelberg outcome may be even more beneficial than the Cournot-Nash outcome to both nations. Restricting our attention to a Stackelberg equilibrium where Home's firm is the leader and Foreign's firm the follower, we can safely exclude such a possibility if either $U^L/U^C < 1$ or $U^{*F}/U^{*C} < 1$ is satisfied. Each of these conditions can be expressed as (28) and (29) in terms of the environment-related parameters. **Q.E.D.**

[3]Recall that (29) is meaningful only if $\alpha^* < 1/2$ since any value of $\alpha^* > 1/2$ leads to $U^{*C} > U^{*F}$ trivially.

Again, as in the symmetric case above, the autarkic situation always constitutes a subgame perfect Nash equilibrium outcome of the whole game. However, this equilibrium is weakly dominated by the other equilibrium outcome of the Cournot-Nash type competition when the conditions of Proposition 2 above are met.

In addition to the Cournot-Nash type competition, a Stackelberg type competition which also weakly dominates the autarkic situation can arise in this asymmetric case.

Proposition 3. *When s, α, s^*, and α^* satisfy the following four conditions simultaneously, the Stackelberg-type competition with Home's firm being the leader and Foreign's firm being the follower emerges as a subgame perfect Nash equilibrium outcome.*[4]

$$s < \frac{5}{4\alpha(3+2\alpha)}, \tag{30}$$

$$s < \frac{25}{4(2-\alpha)(10+7\alpha)}, \tag{31}$$

$$s^* < \frac{1}{4\alpha^*(2+3\alpha^*)}, \tag{32}$$

$$s^* > \frac{11}{4(1-2\alpha^*)(10\alpha^*+7)}. \tag{33}$$

Proof. In order for this Stackelberg outcome to be a Nash equilibrium of the intergovernmental game, first of all, the Stackelberg outcome has to be superior to the autarkic outcome for both countries. Such conditions are given by $U^A/U^L < 1$ and $U^{*A}/U^{*F} < 1$, which are respectively translated into (30) and (32). Moreover, these two countries must simultaneously be better off under the Stackelberg equilibrium in comparison with the Cournot-Nash equilibrium. Hence, it must be the case that $U^L/U^C > 1$ or $U^{*F}/U^{*C} > 1$, which are respectively transformed into (31) and (33). **Q.E.D.**

The region of having this type of Stackelberg competition as a subgame perfect Nash equilibrium outcome is depicted as region S and S^* in the $\alpha - s$ space in Figure 3. It

[4] In order for (32) and (33) to be satisfied simultaneously, we need $11/2(1-2\alpha^*)(10\alpha^*+7) < 1/4\alpha^*(2+3\alpha^*)$ which is ensured under $\alpha^* < (-26+12\sqrt{15})/53$.

should also be noted that a symmetric argument can be made for the case where Foreign's firm is the Stackelberg leader and Home's firm is its follower.

(Figure 3 around here)

When neither of the conditions of Proposition 2 and Proposition 3 is met, autarky is the only equilibrium outcome. Similarly to the symmetric case above, when its marginal cost of pollution is sufficiently high given the pollutant import coefficient, the government tends to be strictly better off by remaining in the autarkic situation and, as a consequence, the international trade of Good 1 may not materialize between the two countries. Even when the Cournot-Nash outcome is dominated by the autarkic outcome for both countries, under the conditions of Proposition 3 the Stackelberg outcome can also be an equilibrium and free trade is beneficial to the two countries in this asymmetric case. Hence, we can state, at least, in the context of our analytical model, that gain from trade is more likely to be captured by each country with stronger dissimilarity in the environmental characteristics across the country.

In view of Proposition 3, we can obtain further insights into the nature of a Stackelberg outcome. Firstly, it implies that, in order for a Stackelberg equilibrium to exist, there needs to be a country with a very small import coefficient for the transboundary pollution. This country must also have a sufficiently high value of the marginal damage cost of pollution. If these two conditions are concurrently met, this environmentally-conscious country would be willing to have its firm become the Stackelberg follower since its consumers benefit from a lower price due to the expanded supply of Good 1 but does not have to suffer too greatly from the transboundary pollution due to the associated expansion of production in the other nation as long as the value of the pollutant import coefficient is sufficiently small.

Secondly, if there exists a Stackelberg equilibrium, it is always the case that the firm in a country with a lower marginal damage cost of pollution becomes the Stackelberg leader. The country whose firm is the Stackelberg leader is going to experience a significant increase in its domestic production of the polluting good. A country with a lower value of s is more resistant to the environmental damages associated with the expanded domestic production and likely to assume the role of the Stackelberg leader.

In one extreme case of $\alpha = \alpha^* = 0$, i.e., when the pollution problem is completely localized, all the three outcomes are possible, depending on the magnitude of marginal damage cost of pollution, s. When $s < \frac{5}{16}$ and $s^* > \frac{11}{28}$ simultaneously hold, the Stackelberg type competition with Home's firm being its leader becomes an equilibrium outcome. When $s > \frac{11}{28}$ and $s^* < \frac{5}{16}$ simultaneously hold, on the other hand, the Stackelberg type competition with Foreign's firm being its leader becomes an equilibrium outcome. When both $\frac{5}{16} < s < \frac{5}{7}$ and $\frac{5}{16} < s^* < \frac{5}{7}$ hold, the Cournot-Nash type competition can materialize. For any other combinations of s and s^*, autarky is the only equilibrium outcome. It should be noted that, even when one country's marginal damage cost is very high, the gain from trade can be reaped by each country in a localized pollution problem, provided that the other country's marginal damage cost of pollution is sufficiently low, due to the potential existence of a Stackelberg equilibrium in the asymmetric case in comparison with the symmetric case.

In the other extreme case of $\alpha = \alpha^* = 1$, on the other hand, the Stackelberg-type competition never occur since no country would be content with allowing its firm to become the Stackelberg follower. If either $s > \frac{5}{28}$ or $s^* > \frac{5}{28}$ holds, autarky is the only equilibrium outcome and, otherwise, the Cournot-Nash type competition can also be an equilibrium outcome. In the case of global pollution, therefore, the result here is essentially the same as in the symmetric case.

5 Concluding remarks

Our analytical findings might provide some new insights into practical policymaking issues surrounding trade liberalization when a transboundary pollution problem is one of each government's interests. Trade liberalization in a good whose production generates transboundary pollutant emissions has two opposing effects: procompetitive effect and pollution-expansion effect. The welfare implications of these effects of international trade could be contingent on certain environmental characteristics of each country, among other things.

In our particular inter-governmental game, the governments can intervene the market solely with respect to the timings of their firms' entering into the international market and, consequently, determine the roles of their respective firms there. The results of our analysis indicate that the marginal damage cost of pollution and the transfer coefficient of transboundary pollution might play significant roles in determining not only the existence of net gain from trade but also the actual type of competition in the international market of such an product. Our results also imply that the shape of the international market and the existence of net gain from trade can possibly switch over time, as these environmental parameters take different values due, for instance, to the change in the citizens' environmental taste and the development of new technologies to improve the protective capacities of the societies against environmental threats.

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Home\Foreign	1	2	no trade
1	U^C, U^C	U^L, U^F	U^A, U^A
2	U^F, U^L	U^C, U^C	U^A, U^A
no trade	U^A, U^A	U^A, U^A	U^A, U^A

Figure 1: Payoff matrix of the timing game

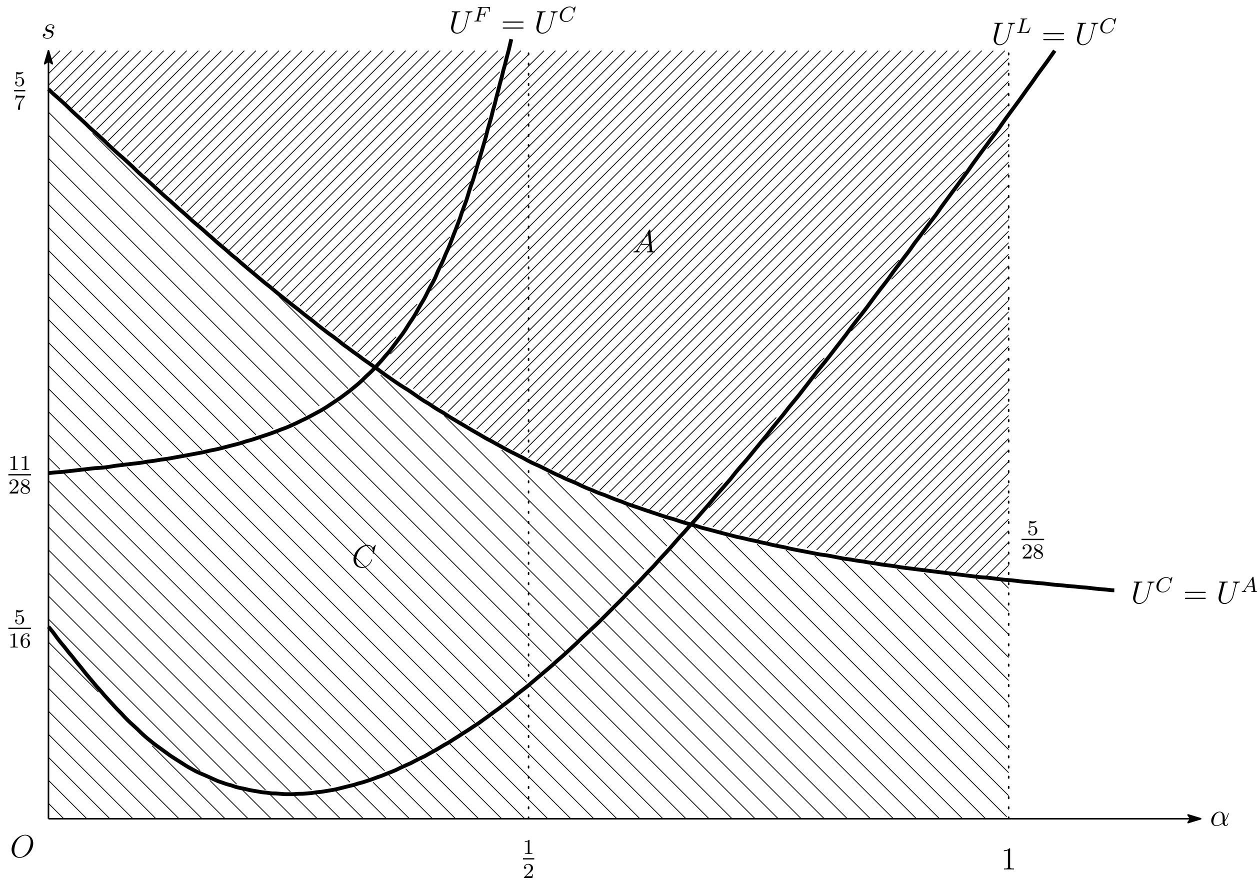

Figure 2: Regions for Cournot-Nash and autarkic outcomes in the symmetric case

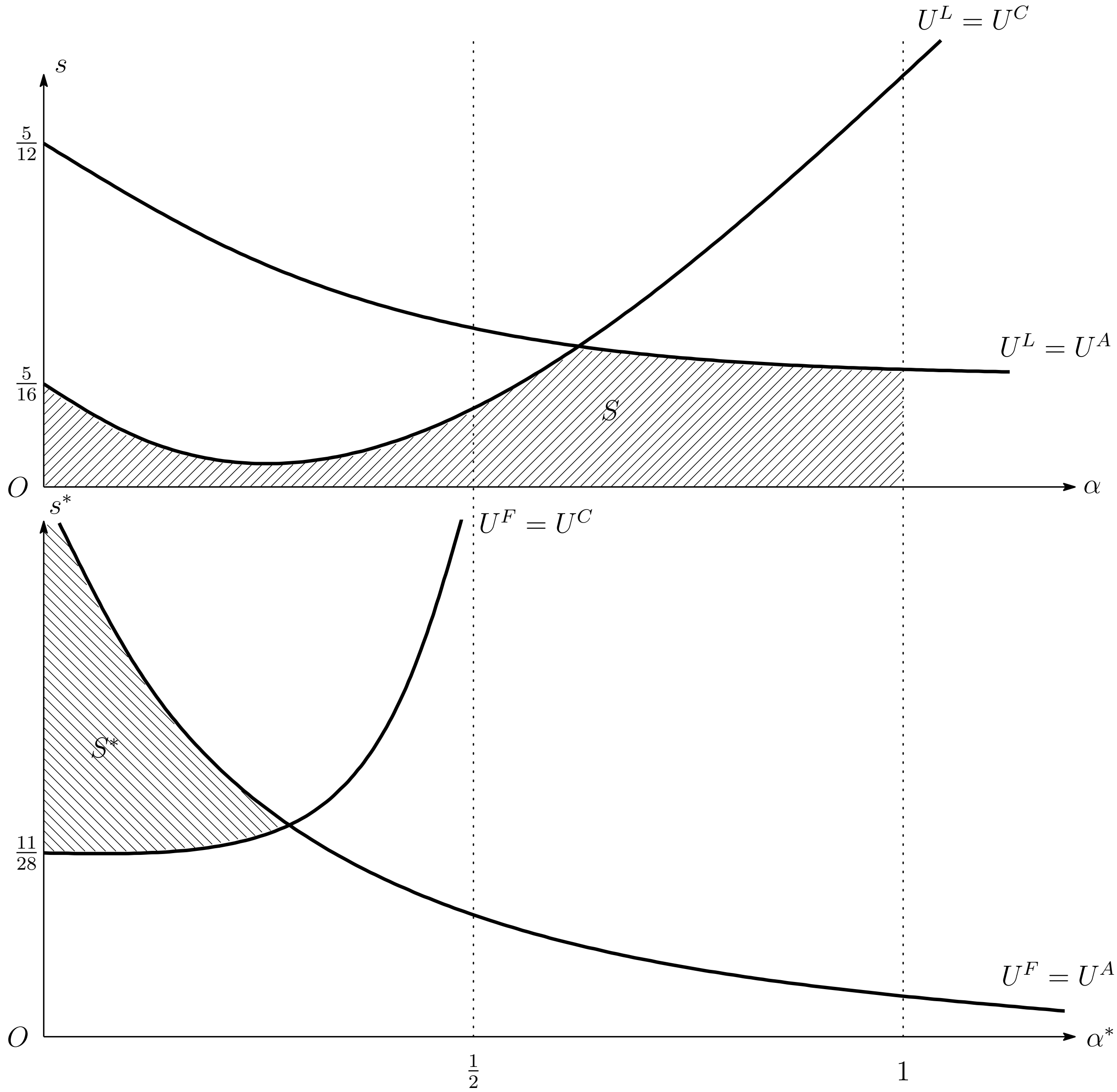

Figure 3: Regions for a Stackelberg outcome in the asymmetric case